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Survey of anthracnose (*Colletotrichum gloeosporioides*) on mango (*Mangifera indica*) in North West Ethiopia

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Abstract

Field surveys were conducted in North West Ethiopia, Pawi district during 2011 and 2012 cropping seasons to determine the distribution of anthracnose and the association of disease parameters (incidence and severity) with climatic variables and crop management practices. Nineteen mango fields were surveyed and all were infected by anthracnose. The surveyed fields were at two growth stages, with flowering (2011) and fruiting (2012). There was no statistically significant difference for the incidence of anthracnose between the two seasons with mean disease incidence of 65.7% in 2011 and 66.5% in 2012. However, severity of anthracnose was statistically significantly different ($p < 0.05$) in 2012 cropping season (81.2%) than in the 2011 cropping season (59.8%). Regression analysis for the relation between agronomical variables, as independent variables, and mango anthracnose severity, as dependent variable, showed contributions of environmental and agronomical variables such as planting stage, field size, plant density, altitude and villages for statistically significant anthracnose severity during fruiting stages than flowering stages. As altitude increases, disease severity decreases in the survey villages in Pawi district, Ethiopia.

Key words – *Bacillus* – biocontrol – incidence – severity – *Trichoderma*

Introduction

The genus *Mangifera* contains several species that bear edible fruit, but most of the fruit trees commonly known as mango belong to the species *M. indica* L., family Anacardiaceae (Bally 2006). Mango is an important fruit crop in tropical and subtropical countries, but productivity is considered to be very low. The low productivity is mainly due to the associated disease problems. Diseases which are of great economic importance are anthracnose, powdery mildew, die back, Phoma blight, bacterial canker and red rust. Of these diseases anthracnose is economically the most important, causing heavy losses in mango production (Okigbo & Osuinde 2003, Pernezmy & Marlatt 1993, Nelson 2008). Akem (2006) showed that anthracnose is presently recognized as the most important field and post-harvest disease of mango worldwide. Anthracnose is the major disease limiting fruit production in all mango growing countries, especially where there is high

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humidity during the cropping seasons. Anthracnose disease is of widespread occurrence causing serious losses to young shoots, flowers and fruits under favorable climatic conditions of high humidity, frequent rains and a temperature of 24–32 ^{0}C (Randon et al. 2006). Anthracnose also affects fruits during storage.

Heavy infections cause rapid rotting, and even light infections, which cause mainly cosmetic damage, will shorten fruit storage life. Because of variability between seasons and locations, overall figures for losses are difficult to give, but losses of up to 50% of the crop to the various stages of the disease would be common (Okigbo & Osuinde 2003). Mango grows over a wide range of frost-free climates. The tree produces best in climates that have a well defined, relatively cool dry season with high heat accumulation during the flowering and fruit development period (Douthett 2000). Rain or free moisture (high humidity, heavy dew, and fog) during the flowering and fruiting period is conducive to the development of fungal diseases that cause flower and fruit drop (Jain et al. 2008). Mangos optimum growing temperature is 24–27 ^{0}C (Bally 2006). The best climate for mango has rainfall of 750–2500 mm in the four summer months (June to September) followed by eight months of dry season (Ramakrishna et al. 1999). Mango is now cultivated throughout the tropics and sub-tropics for commercial fruit production, as a garden tree, and as a shade tree for stock.

Different production practices can influence disease occurrence, epidemic development and damage to crops. Field size and slope of a farm can also affect the development of disease epidemics (Samuel et al. 2008). Disease severity may be influenced by farming systems, field location and/or season.

Management of disease requires understanding of factors that contribute to epidemics. Survey data are useful for gaining insights into the occurrence, distribution and relative importance of different crop diseases (Talhinhas et al. 2009). Very little survey work has been done for mango anthracnose in Ethiopia, especially in north Ethiopia where such information is totally lacking. For effective integrated management of mango anthracnose, knowledge of the relationships of the disease with different variables is very important (Estrada et al. 2000). Ethiopia is one of the countries in which mango is grown as an important source of food and income, in lowland areas such as Pawi, where incidence and severity of infection by this pathogen is favoured by temperatures ranging from 20–30 ^{0}C and a relative humidity of 80–95%. The objectives of this study were to assess the incidence and severity of mango anthracnose diseases in north Ethiopia (Pawi) and investigate the relationship of disease intensity with climatic and agronomical variables.

Materials and methods

Description of the study area

Pawi district is one of the 20 districts found in Benishangul-Gumuz Regional State, in North West Ethiopia. Pawi is located at 11^{0}19’59.47 N latitude and 36^{0}25’00.66 E longitude with an altitude range of 980–1300 metre above sea level (m.a.s.l.). Pawi district is 556 km away from Addis Ababa and about 300 km away from Bahir Dar. The district receives an average monthly rainfall of 107 mm and has a uni-modal pattern, occurring from May to November. The monthly average maximum and minimum temperatures are 24.1 ^{0}C and 12.0 ^{0}C, respectively and the mean annual relative humidity is 40.5%.

Survey of mango anthracnose

Survey area

Mango crop were surveyed in eight mango growing villages of Pawi district of northern Ethiopia, Benishangul Gumuz region during 2011 (flower stage) and 2012 (fruit stage) cropping season. Nineteen fields were inspected for disease incidence and severity from December 22–27, 2011 during flowering stage and repeated during fruiting stage from March 24–29, 2012. Fields were sampled randomly at intervals of 5–10 km along roads, and distances between fields depended on the topography and the relative importance of mango cultivation within each village. The slope of each inspected field was measured using GPS (Global Positioning System).

Disease assessment

Nineteen farmers fields 2–3 km apart were visited in six Pawi villages, using random sampling methods, from each field 3–4 plants were randomly selected by walking in an "X" fashion across the farm for measuring disease incidence and severity. The number of healthy and anthracnose infected leaves of plants within the area was recorded.

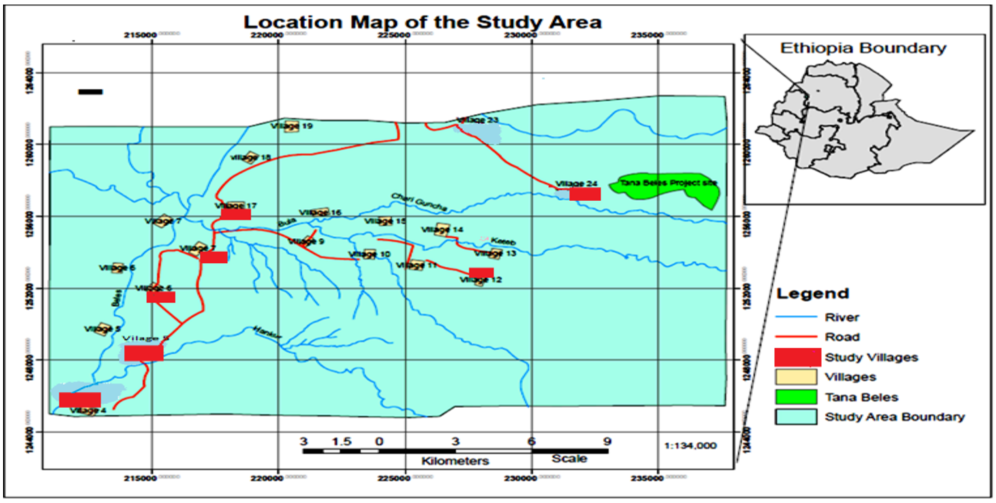

Fig 1 Map of Ethiopia and the villages surveyed for mango anthracnose in Pawi district, Benishangul-Gumuz Regional state (Source the Ethiopian Map Works Agency).

Anthracnose incidence was rated as mean percentage of diseased plant leaves within the field. Severity was rated on leaves from the same 3–4 representative plants in each field, using a 1–9 scale, where 1 indicates no visible symptom and 9 represents disease covering more than 80% of the foliar tissue (Masood et al. 2010).

Disease severity scores from survey were converted into percentage severity index (PSI) for the analysis.

$$\mathrm{PSI} = \frac{\text{Sum of numberical rating}}{\text{Number of plants scored X maximum score on scale}} \; X\,100$$

Agronomical practices, such as field size, cropping pattern, cropping systems, altitude, planting date, topography, precipitation, weeding conditions, fertilizer usage, soil type, plant growth status and plant density were also assessed to determine their relationship with the disease intensity and distribution.

Data analysis

Disease incidence and severity were classified into distinct groups of binomial qualitative data. Thus, $\leq$ 75 and >75% were chosen for incidence yielding a binary variable. Class boundaries of $\leq$ 75 and >75% were chosen for severity data. Contingency tables of disease incidence and severity and the independent variables were built to represent the distribution of fields according to data classifications. Disease incidence and severity (PSI) were analyzed using SPSS version 16.0. Survey data of agronomic characters, disease incidence (%) and severity (%) were analyzed using analysis of variance (ANOVA).

Results

General features of the surveyed fields

The altitudes ranged from 1040 m in village 5 to 1205 m in village 24. Only 1% of the farmers were using compost fertilizer in mango fields. From the survey of the farm types it was observed that 89.5% of the fields were sole-cropped, while 10.5% had mixed cropping. Crops commonly associated with mango in mixed cropping were coffee, lemon and papaya. One percent of the surveyed fields had row planting type while the rest had broadcast planting. Mango fields were at two growth stages during the survey; flowering, and fruiting stage. The highest anthracnose disease incidence (95.5%) was observed in villages 4 and 5. Village 5 had the highest disease severity (100%) while the lowest severity was observed in village 24 (33.3%).

Table 1 Categorization of variables used in analysis for the survey data of mango in Pawi, 2011 and 2012 (n = 38).

Variable	Variable class	No. of fields with anthracnose			
		Incidence		Severity (PSI)	
		≤75	**>75**	**≤75**	**>75**
District villages	Village 4	4	2	1	5
	Village 5	5	3	2	6
	Village 6	4	2	0	6
	Village 7	5	1	0	6
	Village 12	3	3	1	5
	Village 24	6	0	6	0
Cropping pattern	Sole	22	12	7	27
	Mixed	2	2	3	1
Slope of farm	≤ 8%	25	11	9	27
	>8%	1	1	1	1
Plant density (ha)	≤ 0.05	9	2	9	3
	>0.05	19	8	13	13
Growth stage	Flowering	15	4	17	2
	Fruiting	12	7	5	14
Year	2011	15	4	17	2
	2012	12	7	5	14
Total no. of fields	76	27	11	22	16

* Incidence is number of leaves infected and expressed as a percentage of the total number of leaves assessed.

*Severity is percentage severity index (PSI) of anthracnose infection on the plants.

Disease incidence and severity

Different levels of anthracnose incidence and severity were recorded among the villages. The mean disease incidence was 65.7% in 2011 (flowering stage) and 66.5% in 2012 (fruiting stage). Highest mean disease incidence in 2011 was recorded in villages 4, 5 and 7 (71–74.2%) and lowest was recorded in villages 12 and 24 (48.5% and 58.8%).

Table 2 Mean incidence and severity (PSI) of mango anthracnose for different independent variables in 2011–2012 cropping seasons in Pawi district.

Variable	Variable class	Anthracnose			
		Incidence		Severity (PSI)	
		Mean	SD	Mean	SD
District Villages	Village 4	71.4	20.9	73.3	18.5
	Village 5	74.2	19.1	76.4	19.2
	Village 6	70.4	14.3	75.8	11.9
	Village 7	71	11	79.4	10.7
	Village 12	58.8	27.2	69.5	8.4
	Village 24	48.5	13.9	46.6	22.1
Cropping system	Sole	65.5	18.4	71.4	18.3
	Mixed	69.3	26.6	65.5	20.9
Slope of farm	≤ 8%	65	19.4	70	19
	> 8%	85	14.4	78	1.6
Plant density /ha	≤ 0.05	52.1	16.2	54.7	22.3
	> 0.05	67.5	12.9	68.5	16.9
Altitude	≤ 1070	66	20.4	69.1	15.2
	> 1070	65.9	14.9	71.1	15.2
Field size (m^2)	≤ 5000	53.9	13.1	58.5	20.3
	> 5000	74.9	14	79.4	14.4
Growth stage	Flowering	65.7	16.1	59.8	19
	Fruiting	66.5	22.9	81.2	10.5
Year	2011	65.7	16.1	59.8	19
	2012	66.5	22.9	81.2	10.5

Disease severity showed a very similar trend. The highest mean disease severity ranged from 73.3 to 79.4% at villages 4, 5, 6 and 7, and lowest ranged from 46.6 to 69.5% in village 24 and 12, respectively. Village 7 had the highest ($P < 0.05$) disease severity (79.4%) among all the villages. Anthracnose also showed significant variation in disease severity at flowering and fruiting stages. The highest disease severity was observed at the fruiting stage (100%) and the lowest at flowering stage (33.3%)

Association of disease parameters with agronomic practices

The regression coefficients for plant density, field size, growth stage and altitude showed that there is a significant regression coefficient ($p < 0.05$) in increasing the disease severity when associated with the years. However, only villages have significant association in increasing both diseases incidence and severity.

The regression coefficient for the plant density using plant density as an independent variable and severity as dependent variable showed significant ($p <0.05$) contribution in variation of diseases severity in 2011 and 2012 cropping seasons. Compared to other independent variables the adjusted R^2 for regression coefficient of plant density and field size were 0.4 (40%) and 0.39 (39%), respectively. This shows that plant density and the size of survey fields have about 40% and 39% contribution in increasing disease severity due to ease of spore dissemination and complex re-infections between mango plants. Linear regression relating anthracnose severity with field size showed that larger fields have less mean disease severity than smaller fields. Altitude of mango fields in the villages contribute about 43% in increasing disease severity, but as altitude increases, disease severity decreases, that is 46.6% at 1142–1205 m.a.s.l. in village 24 and 73.3–69.5% from villages 4–12 with an altitude range of 1025–1097 m.a.s.l.

Table 3 Adjusted R^2 from the linear regression model in environmental and cropping system variables.

Predictors (independent variables)	**Coefficients**	**Adj. R^2**	**Standard error**	**P (probability,005)**
Years	0.582	0.32	15.35	0.00
Plant density	0.302	0.397	14.4	0.024
Village	-0.558	0.629	0.271	0.00
Field size	0.291	0.39	6.1	0.03
Stag	0.582	0.32	15.3	0.00
Altitude	-0.396	0.466	0.048	0.002

Table 4 Adjusted R^2 from the linear model in environmental and cropping system variables (predictors) accounting for year effects.

Predictors (independent variables)	**Variable category**	**Dependent variables**							
		Incidence				**Severity**			
		Prediction	**SE**	**Adj.R^2**	***P***	**Prediction**	**SE**	**Adj.R^2**	***P***
Slop	< 8%	65.12	3.24			70.06	3.17	0.312	0.01
	> 8%	85.25	10.24			78.85	1.15		
Cropping system	Sole	65.59	3.26			71.46	3.24	0.315	0.01
	Mixed	69.33	10.87			65.51	8.57		
Villages	4	71.41	8.54	0.163	0.017	73.38	7.5	0.629	0.00
	5	74.25	6.78			76.4	6.81		
	6	70.41	5.84			75.88	4.85		
	7	71	4.52			79.4	4.39		
	12	58.83	11.11			69.5	3.43		
	24	48.5	5.7			46.63	9.05		

Survey villages also have significant contribution with higher adjusted regression coefficient of 63% for severity, which is in line with Samuel et al. (2008) but 16.3% for incidence. This difference indicates that variations in environmental conditions in the villages such as temperature, humidity, wind speed, and inoculum pressure have contributions for the resulting disease severity and incidence during the cropping seasons.

The regression coefficients for field size and plant density showed that there is significant regression coefficient ($p < 0.05$) in increasing the disease severity in association with the years.

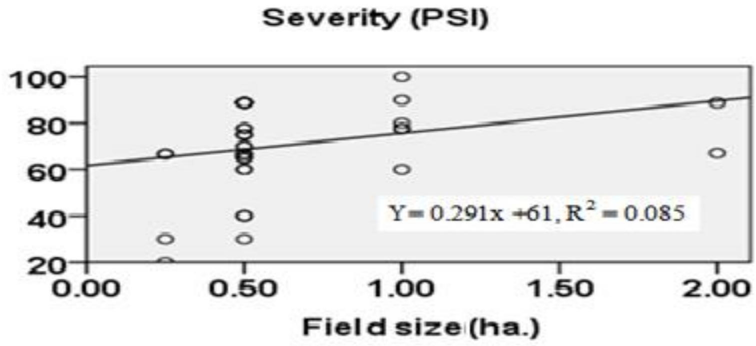

Fig 2 Linear regression relating anthracnose severity with field size.

Environmental factors such as low temperature, low humidity and low wind speed during flowering stage (2011) and high temperature, high humidity, and high wind speed during fruiting stage (2012) have about 32% effect for significant difference in severity during growth stages or cropping seasons. Slope of the mango fields and cropping system had slight contributions, 3.12% and 3.15% in increasing diseases severity. This showed that diseases severity in Pawi district was less dependent on slope of surveyed farm and cropping systems in the farmers' mango fields.

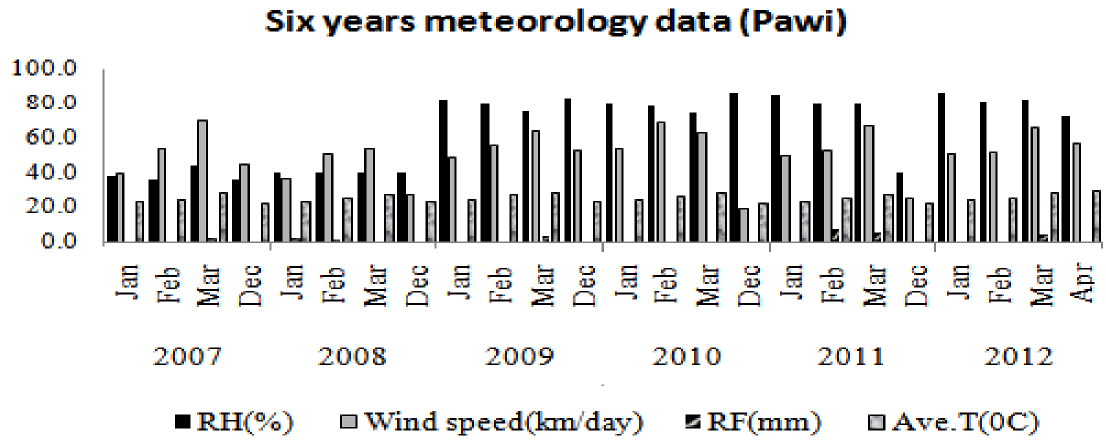

Fig 3 Six years meteorology data, Pawi district, showing RH (relative humidity), wind speed, RF (rainfall) and Ave. T (average monthly temperature in ^{0}C) (Source: National Meteorological Service Agency).

Discussion

During the survey periods, anthracnose was widely distributed in all villages, but the survey showed variations. The minimum mean severity of 46.6% was recorded in village 24, while the maximum mean severity of 79.4% was recorded in village 7. The mean incidence ranges from 71% to 74% in villages 4, 5 and 7 while severities were 73.3 to 79.4%. The diseases survey result showed higher incidence and severity of anthracnose in village 7 while the lowest was in village 24.

Comparing flowering stage and fruiting stage, there was no significant difference for the incidence of anthracnose, showing that incidence of anthracnose was independent of planting and other independent variables, except villages. Severity of anthracnose was significantly higher ($p<0.05$) during fruiting stage than flowering stage. The difference can be attributed to the higher relative humidity associated with high temperature during fruiting stage, which provides favorable environmental conditions for anthracnose development after infection (Estrada et al. 2000). The anthracnose pathogen is most serious at high moisture and warm temperature (Noriega-Cantu et al. 1999). In drier situations, disease expression can occur when latent infections are activated through aging or tissue damage (Medeiros et al. 2010). In addition to higher temperatures during 2012 cropping season than 2011, the higher disease severity recorded during 2012 can also be due to inoculum abundance resulting from the 2011 outbreak. This suggests that *C. gloeosporioides* acts as an opportunistic pathogen, responding to favorable environmental conditions and high inoculum pressure (Talhinhas et al. 2009). The existence of a widespread inoculum reservoir on mango orchards and other fruit varieties in the area is considered the other main reason for the disease being so common, and for frequently causing severe losses in Pawi.

Conclusion and recommendations

From survey results two main mango diseases were identified, anthracnose and powdery mildew. *C. gloeosporiodes* and *C. acutatum* were identified as the causative agent for the anthracnose of mango in Pawi district. The present study showed high incidence and severity of mango anthracnose in Pawi district with significant difference of diseases severity during survey periods, 2011 and 2012 cropping seasons. Although meteorological conditions during survey periods were not significantly different, higher disease severity and incidence recorded can be due to inoculum abundance resulting from previous outbreak, high temperature, high humidity and wind speed. The existence of a widespread inoculum reservoir on mango orchards and other fruit varieties in the area are also considered the main reasons for the disease being so common in the district. Regression analysis for the relation between independent variables and disease parameters showed contribution of planting stage, field size, plant density, altitude and villages in increasing disease severity in Pawi district.

Despite limitations to the study, especially short survey period, the following are recommendations based on the survey findings.

- High mango anthracnose incidence and severity in Pawi district needs massive chemical treatments, especially during flowering season to minimize severe losses of mango fruits due to anthracnose.
- There should be practice of cultural management such as removal of mango plants with large inoculum pressure to minimize mango anthracnose incidence and severity in the district.
- Survey in this study was conducted for only two cropping seasons; additional continuous years rounded survey is required to identify the relation between environmental factors, agronomical practices and mango anthracnose.
- Farmers should be trained about pre- and post-harvest effects of mango anthracnose and possible management options such as cultural control and chemical control with proper applications for prevention and control of mango anthracnose.

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